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ABSTRACT

The effect of playing a logic game, Master Mind, on student learning in physics was examined in this study. An experimental group of 16 Electronics Engineering Technology students played the game during class one hour per week for seven weeks. A control group of nineteen students took the course without playing the logic game. Results showed that use of the logic game developed reasoning ability to the extent that the experimental group performed better on physics exams than the control group. Because of the abstract nature of physics, understanding requires formal operational thought, however many college students are still in the concrete operational stage. Transition into the formal stage is possible if the student encounters problems requiring formal level thought while dealing with concrete objects. The logic game used in this study provided the student with non-verbal, non-mathematical, concrete experiences with hypothesis testing and control of variables. Physics laboratory exercises are analogous to the logic game in that they also require formal level thought. Further study is recommended to verify the value of the logic game as an aid to cognitive development. (TP)

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THE EFFECT OF PLAYING A LOGIC GAME ON STUDENT LEARNING IN PHYSICS

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ABSTRACT

This study examined the effect of playing a logic game, Master Mind, on student learning in a course in mechanics. An experimental group of sixteen Electronics Engineering Technology students played the game during class time one hour per week for seven weeks. A control group of nineteen students from the same curriculum took the course without playing the logic game. The groups were found to be equal in terms of school entrance test scores.

Student learning in physics was measured by an exam. The exam scores correlated well with the students' chapter test scores. The results showed that the experimental group performed better in the exam than the control group. Students' t-test was used and the level of significance was beyond the 0.001 level.

The significance is that understanding in physics requires formal operational thought but many college students are still in the concrete operational stage. Transition into the formal stage can be made if the student encounters problems requiring formal level thought while dealing with concrete objects. The logic game required formal level thought and had the advantage of being nonverbal.

Further study is recommended to verify the value of the logic game as an aid to cognitive development. It is also recognized that physics laboratory exercises are analogous to the logic game in that they can be made to require formal level thought while dealing with concrete objects.

TABLE OF CONTENTS

		Page
I.	TITLE	1
II.	PROBLEM	1
III.	HYPOTHESIS	1
IV.	BACKGROUND AND SIGNIFICANCE	1
V.	DEFINITION OF TERMS	6
VI.	LIMITATIONS OF THE STUDY	7
VII.	BASIC ASSUMPTIONS	7
VIII.	PROCEDURES FOR COLLECTING DATA	8
IX.	PROCEDURES FOR TREATING DATA	9
X.	RESULTS	10
XI.	CONCLUSIONS AND SIGNIFICANCE	13
	REFERENCES	15
	APPENDIX	
	A. RULES FOR PLAYING MASTER MIND	16
	B. PHYSICS EXAM	17

I. TITLE

The Effect of Playing a Logic Game on Student Learning in Physics

II. PROBLEM

This study examined the effect of a particular activity on student learning in a physics class. The activity was the classroom use of a logic game sold under the trade name of Master Mind. Learning was measured by student performance on a physics exam.

The independent variable was student use of the logic game. The dependent variable was the scores on the physics exam.

III. HYPOTHESIS

It was expected that this study would show that use of the logic game will develop reasoning ability to the extent that students will perform better on a physics exam than students who do not use the logic game.

The null hypothesis is that students who use the logic game will perform no differently on a physics exam than students who do not use the logic game.

IV. BACKGROUND AND SIGNIFICANCE

Many students entering physics courses have little chance of understanding the process of the discipline. This is not a problem that is unique to the "new" student in post-secondary education although it may be more common today than ever before. It is almost an educational tradition that physics is a difficult course that can be mastered by only a small percentage of students. The reason for this may lie in the abstract nature of physics. Writing on the levels of though and content in physics courses, Renner and Lawson (1973b: 274) describe the difficulty involved.

> The abstractions in physics. . . are in actuality models created by scientists to explain observable data. These models do not arise directly from the observations; rather, they simply represent attempts to construct an explanation or model which implies what is observed. The scientist creates the model and reasons <u>if</u> his model is true, <u>then</u> consequences should be found. If the predicted consequences are indeed found, he has <u>therefore</u> supported his model. This process is hypothetico-deductive or in the if. . . , then. . . , therefore. . . form. For a student to fully grasp the meaning of the abstract models he, too, must be able to think in the if. . . , then. . . , therefore. . . form.

Piaget's stage theory of intellectual development can be used to explain why many students cannot deal with the abstractions of physics. In Piaget's theory, an individual's mental stage is characterized by the cognitive operations that he is capable of carrying out. From birth to adulthood the individual must pass through a fixed sequence of periods in his intellectual development. Adolescents and adults are either in the concrete operational period, the formal operational period, or in transition between the two periods.

The concrete operational period is described by Travers (1977: 191) as follows.

> The child does not formulate hypotheses and seems quite unable to pursue such a line of abstract thought because he is so data bound. Piaget says that the child at the stage of concrete operations is very objective, in that he deals with the facts at hand, but it is this matter of being tied to the facts that limits his thinking.

Eventually the concrete operational person encounters problems that cannot be handled by his mental structures. This produces a state of disequilibrium. If the environment is appropriate the individual can develop new mental structures and progress into the next period. In moving from concrete to formal operations the basis for the new thought patterns must be concrete materials. The individual cannot abandon concrete experiences all at once.

The last period in mental development is "characterized by the logic of propositions, the ability to reason from a hypothesis to all its conclusions. This involves thinking about thoughts or theories rather than concrete realities." (Pulaski, 1971: 208) The concrete operational student can deal with observable facts and relationships but cannot generalize his observations to include situations outside his experiences. The formal operational student is fully developed in terms of cognitive structures and is not bound by the "here and now."

Recent attention to Piagets' theories has led to the discovery that college students are not as intellectually developed as might have been supposed. Griffiths (1976: 33) reports that a random sampling of 30 second-semester physics and chemistry students at Rutgers University were tested and only 34% were found to be formal operational. In a separate part of the same study, 30 students in non-transferable developmental science and physics courses at Essex County College were tested and only 27% were found to be formal operational. McKinnon and Renner (1971: 1048) studied the responses of 131 freshmen at an Oklahoma university to some tasks designed by Inhelder and Piaget. They found 25% were formal operational, 50% were concrete operational, and 25% were in transition between the two stages. Using two Piaget-type tasks, Kolodiy (1975: 21) tested high school sophomores, college freshmen, and college seniors. He found upper level formal operations in 35%, 32% and 64% respectively. In all of the studies reported here, the testing was by tasks similar to physics laboratory exercises and the subjects were most often scored on ability to identify and control variables. The results of the studies are more suggestive than definitive. We are cautioned by Travers (1977: 197) that because the research of Piaget and his associates is far less complete regarding formal operations level than

it is at earlier levels, ". . . There are virtually no criterion that can be rigidly applied to determine whether the adolescent is or is not able to perform formal operations."

Given the situation that possibly as many as one-half of entering college students have incomplete mental structures, a question arises. Should we attempt to coordinate our teaching methods and course content to the existing abilities of the students or should we attempt to facilitate the development of higher level cognitive structures. A report by the Carnegie Commission on Higher Education (1973) concluded that one of the main purposes of education in the United States today and for the prospective future is "The provision of opportunities for the intellectual . . . development of individual students. . . " But, after studying the data on student intellectual abilities, Arnold Aarons, professor of physics at the University of Washington, concludes that "We face the implication that our educational system is not contributing to intellectual development." (Mitzman, 1978: 52)

It is generally considered that the study of certain subjects such as mathematics, especially geometry, and the physical sciences and other liberal arts is for the development of the intellectual powers or the reasoning facilities. However, Symons (1970: 75-90), in a summary of research related to transfer of learning and formal discipline, reports the following.

> The evidence is conclusive and the conclusion inescapable that one does not achieve mental power by means of a particular subject of study. Mental power - intelligence- if it can be achieved through study must come not by virtue of the subject matter but through the methods employed and hence learned. Mental growth depends primarily on how a subject is taught and on the emphasis in its teaching.

It is not what the student learns but how he learns it that contributes to intellectual growth. The failure of the educational system in this

respect may be due in part to faulty assumptions about the student. An assumption which could be generalized to all disciplines is pointed out by Griffiths (1976: 82) writing about the teaching of physics and intellectual development. "The basic premise underlying college science instruction . . . is . . . that students are fully capable of operating at the level of formal operational thought by the time they enter college."

When the assumption that entering college students are formal operational thinkers has been abandoned, the question arises, "How can the transition from concrete operational thought to formal operational thought be promoted?" Researchers in physics education are looking to Piaget for help in developing instructional techniques that will promote this transition. The result has been a changing emphasis in some experimental courses away from the content of physics and toward the process of physics.

At the University of Washington, Arnold Aarons operates an introductory physical science course where students learn by having "Direct personal experience with the phenomena, evidence, inference, concept formation, and quantative reasoning." (Mitzman, 1971: 52-55) He reports that the majority of students show significant gains in reasoning ability. Reporting on gains in formal reasoning ability from inquiry-oriented laboratory exercises, Renner (1976: 222) concludes that, "Teachers must discard some of their substitution of mathematical treatment of phenomena for actual experience with the phenomena." In a project entitled Stress on Analytical Reasoning described in Chemical and Engineering News (1977: 25), J. W. Carmichael, Jr. of Xavier University uses chemistry laboratory exercises to promote formal operational thinking. A significant number of students experienced transition from concrete to formal levels during a six-week summer session.

One of the main purposes of higher education is the development of intellectual abilities. At least one-half of the entering college students do not have fully-developed cognitive structures. They are unable to use symbols, think abstractly or use hypothetico-deductive reasoning. If we are to fulfill our purpose-our responsibility to our students - in the area of intellectual development, instructional methods are the key. Course content alone cannot promote intellectual development. Success with the inquiry-approach in physics courses supports the contention of Renner and Lawson (1973a: 166) that formal operational thinking must develop from concrete experiences.

The logic game used in this study provides the student with non-verbal, non-mathematical, concrete experiences with hypothesis testing and control of variables. While playing the game (see Appendix A for rules) the student forms a hypothesis about the order of the colors of a hidden row of pegs. He tests that hypothesis by attempting to duplicate the order of the colors. After receiving data about the accuracy of his hypothesis, the student experiences a concentrated session of if. . . then . . . . thinking with easily understood variables. The logic game is a potentially useful instructional tool in courses that require formal operations, such as mathematics and the sciences, as well as courses that teach study skills. If concrete experiences in hypothesis testing cause cognitive development a rationale will be established for changing the types of experiences students usually have in physics laboratory exercises.

V. DEFINITION OF TERMS

Inquiry-learning - Learning through independent discovery. Rather than being told about relationships or principles, the student is led to discover or invent them for himself.

Logic game - In the context of this study it is a game involving hypothesis testing. Players use incomplete evidence to infer the probable sequence of colors in a row of four pegs.

Physics course - The physics course referred to in this study is a course in mechanics involving statics, kinematics, and energy. It is taught in a conventional manner using lectures, laboratory exercises, and problem solving and meets for five hours per week.

VI. LIMITATIONS OF THE STUDY

This study was conducted with several limitations. The size of the experimental and control groups was small and composed of students from only one curriculum. The results may not be generalizable to students of different interests and academic skill levels. Also, the experimental treatment could not be administered without deleting some normally available experiences. The use of the logic game was substituted for some problem solving practice, not simply added to the normal instructional program.

VII. BASIC ASSUMPTIONS

This study used a pre-experimental design referred to by Campbell and Stanley (1963:12) as a static-group comparison. Two assumptions are associated with this design. The first is that the group selection process did not result in groups with unequal abilities for learning in physics. The second is that no differences were introduced by experimental mortality.

The assumption of equal abilities was verified in part as described in the following sections. The factors of motivation and time for study were assumed to be equal. Experimental mortality was low and assumed to be inconsequential.

Assumptions were also made regarding the validity and reliability of the exam used. The assumption that the exam was valid in terms of content was based on the fact that it contained items covering a wide

variety of course objectives. Construct validity is based on what constitutes learning in physics. The major mental structures indicative of formal level cognitive development and necessary for success on the exam used are the abilities to use proportional reasoning, to use combinatorial logic and to recognize correlations between variables. The exam used is included as Appendix B.

The assumption of criterion-related validity was based on the correlation between the exam scores and the average score on six chapter tests given to the same students during the course. The results are described in a later section. Since the effect to be measured was learning in physics, the external measure used for comparison was a different type of physics test.

The assumption of reliability is based on the same results as the assumption of criterion-related validity. The type and lengzh of the exam used and the number of students involved precluded the use of conventional processes such as test-retest, parallel forms and split halves.

VIII. PROCEDURES FOR COLLECTING DATA

This study was conducted with two sections of first-year electronic engineering technology students. One section began with nineteen students and the other with sixteen students. The section with sixteen students was designated the experimental group because it could evenly be divided into groups of two students each for playing the logic game. The section of nineteen students was the control group. Due to dropouts, the experimental group lost one student and the control group lost two students.

The control group experienced lectures, laboratory exercises, demonstrations and problem solving sessions as is the normal procedure in a physics class. The experimental group had the same experiences except that one hour per week of in-class problem solving practice was replaced

by use of the logic game. After seven weeks both groups were given the same exam on the physics material covered.

The exam was designed to measure the student's understanding of the relationships associated with Newtonian mechanics, his ability to recognize the significant data in a problem, his ability to make reasonable assumptions and to solve a problem in a logical, organized manner. The exam used is included as Appendix B.

To check for equality of academic ability of the two groups, their school entrance test scores were obtained from the Student Personnel office. Nine students in the experimental group and eleven in the control group had taken the Comparative Guidance and Placement (C.G.P.) test. Five students in the experimental group and six in the control group had taken the Scholastic Aptitude Test (S.A.T.).

Student scores on six chapter tests given during the course were recorded for comparison with the exam used as a measuring instrument for the experiment.

IX. PROCEDURES FOR TREATING DATA

The data consisted of two groups of exam scores. The exam scores were analyzed for significance of the difference between the group means by use of Student's two-tailed t-test.

The null hypothesis was tested to the five percent level of significance. A lower level would have been difficult to justify since the exam used to collect data was not rigorously checked for validity and reliability and the student groups were not formed in a random manner. A higher level of significance would unnecessarily increase the probability of making a type I error (rejecting a true hypothesis).

The school entrance test scores were compared to see if either group was academically superior to the other. The groups' scores on the three catagories of the C.G.P. test and on the two catagories of the S.A.T. were compared using Student's t-test.

The data to support the assumptions of criterion-related validity and the reliability of the exam was examined by computing Spearman's rank order correlation coefficient. A five percent level of significance was considered adequate.

X. RESULTS

The results of the test of the hypothesis is shown in Table 1. The value of t required to reject the null hypothesis at the 0.05 level of significance is exceeded. The mean exam score of students in the experimental group was higher than in the control group.

TABLE 1

A Comparison of Exam Scores of Experimental Group and Control Group

	Experimental Group Mean = 59.5 S.D. = 13.6
Control Group Mean = 53.8 S.D. = 16.6	t = 12.024 d.f. = 30

t for rejection of hypothesis at 0.05 level = 2.042
at 0.01 level = 2.750
at 0.001 level = 3.646

The results of the comparisons of the school entrance test scores of students involved in the study is shown in Table 2 and Table 3. The value of t in each comparison is less than that required to reject a no-difference assumption.

TABLE 2

A Comparison of School Entrance Test Scores (C.G.P.) of Students Involved in Study

Control Group	Experimental Group: Reading	Experimental Group: Writing	Experimental Group: Math
	Mean = 65.7 S.D. = 28.2 N = 9	Mean = 61.2 S.D. = 35.2 N = 9	Mean = 80.7 S.D. = 14.4 N = 9
Reading Mean = 61.7 S.D. = 21.7 N = 11	t = 0.353 d.f. = 18 t(.05) = 2.10		
Writing Mean = 61.4 S.D. = 24.1 N = 11		t = 0.018 d.f.= 18 t (.05)= 2.10	
Math Mean = 71.2 S.D. = 24.0 N = 11			t = 1.041 d.f.= 18 t(.05)= 2.10

TABLE 3

A Comparison of School Entrance Test Scores (S.A.T.)
of Students Involved in Study

		Experimental Group	
		Verbal Mean = 420 S.D. = 48.5 N = 5	Math Mean = 520 S.D. = 41.8 N = 5
Control Group			
Verbal Mean = 425 S.D. = 58.9 N = 6	t = 0.151 d.f. = 9 t(.05) = 2.26		
Math Mean = 497 S.D. = 57.5 N = 6		t = 0.754 d.f. = 9 t(.05) = 2.26	

The exam scores were compared with the chapter test averages for each student. A Spearman's rank order correlation coefficient of 0.634 was calculated. This value indicates a positive correlation beyond the 0.01 level of significance.

XI. CONCLUSIONS AND SIGNIFICANCE

It was found that the students who participated in the classroom use of the logic game scored better on a physics exam than those students who did not use the logic game. The data of Table 1 indicate that the result is significant well beyond the 0.001 level. Furthermore the two groups of students participating in the study were found to be academically equal. The data reported in Table 1 and Table 2 show the results of school entrance tests given less than one year before this study was done. During the time between the entrance tests and this study, all students involved took, or received transfer credit for, the same courses.

If the two groups were in fact initially equal in cognitive abilities and if the physics exam was a measure of cognitive ability, then something important happened. Through the use of the logic game, Master Mind, some students experienced cognitive development. They progressed, it would seem, toward, or further into, formal operational thought.

There are, of course, alternate explanations of the results of this study. One possibility is that playing the logic game added an element of interest to the course thus improving student attitude toward studying physics. Also, playing the game might have affected the class as a group causing more competition and/or cooperation in their study of physics. It was, in fact, observed that the experimental group was more talkative in class than the control group. It should also be noted that the differences observed could be the result of the Hawthorne Effect. The experimental group was told about the experiment whereas the control group was not.

The conclusion here is that the relationship studied is worthy of further study. Future studies should attempt to reduce the limitations and assumptions made in this study. The primary limitations were group size and type. The size of the groups should be enlarged and vocational and developmental studies students should be included. Some system should be devised to add the game playing to a course without reducing other activities. Also, a pretest-posttest control group experimental design would produce more reliable results than the design used here.

The type of activity involved in playing Master Mind is that of hypothesis testing and control of variables. These are only two of the mental operations indicative of the formal level of cognitive development. Laboratory exercises in physics, however, have the potential for eliciting many other formal level mental operations. Some examples are the abilities to use proportional reasoning, probablistic reasoning, combinatorial logic and to recognize correlations between variables. If encountering the need to use formal operational thinking while dealing with concrete objects causes cognitive development, the physics laboratory is the place where this should happen. It may be that from the standpoint of the concrete operational thinker, the process of physics is much more important than the content of physics.

REFERENCES

Campbell, Donald T. and Julian C.Stanley
1963 Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally.

Carnegie Commission
1973 The Purposes and Performance of Higher Education in the United States. New York: McGraw-Hill.

Griffiths, David H.
1976 "Physics teaching: does it hinder intellectual development?" American Journal of Physics 44 (January): 81-85.

Kolodity, George
1975 "The cognitive development of high school and college science students." Journal of College Science Teaching 5 (September): 20-22.

McKinnon, Joe W. and John W. Renner
1971 "Are colleges concerned with intellectual development?" American Journal of Physics 39 (September): 1047-1052.

Mitzman, Barry
1978 "Toward a more reasonable physics: the inquiry approach." Change Magazine 1 (January): 52-55.

Pulaski, Mary Ann Spencer
1971 Understanding Piaget. New York: Harper and Row.

Renner, John W. and Anton E. Lawson
1973 "Piagetian theory and instruction in physics." The Physics Teacher II (March): 165-169.

Renner, John W. and Anton E. Lawson
1973 "Promoting intellectual development through science teaching." The Physics Teacher II (May): 273-276.

Renner, John W.
1976 "Significant physics content and intellectual development-cognitive development as a result of interacting with physics content." American Journal of Physics 44 (March): 218-222.

Symonds, Percival M.
1970 What Education has to Learn from Psychology, Third Edition. New York: Teachers College Press.

Travers, Robert M. W.
1977 Essentials of Learning, Fourth Edition. New York: Macmillan.

1977 "Program aims at improving abstract reasoning." Chemical and Engineering News (October 17): 25.

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APPENDIX B

PHYSICS 111 FINAL EXAM Spring 1978 NAME_____

Answer 6 of the following questions. State any assumptions that you make.

1. Describe the motion of a body on which the net torque is zero but the net force is not zero.

2. When two children are balanced on a seesaw, one can go down by leaning backward. Why?

3. A car moving at 30 miles per hour can skid to a stop in 40 feet with the wheels locked. How far will it skid before stopping if it is going 90 miles per hour?

4. How does the weight of a body compare to the air resistance it encounters after it reaches terminal velocity?

5. What kind of motion does a constant net force produce on a body of constant mass?

6. (a) Why is the weight of a car a major factor in its fuel consumption?

   (b) Why does city driving use more gasoline per mile than highway driving?

7. Assume a small stream runs across your property and you are interested in installing a hydroelectric generator to supply your need for electrical energy. What factors would you have to consider and what additional information would you need to determine how high to build the dam?

8. If you decide not to build the hydroelectric plant discussed in the previous problem what becomes of the energy that you would have converted into electricity? Discuss the process involved and the results.

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